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EARLY AMERICAN ASTRONOMERS*

By S. A. MITCHELL

IN THE year 1832, Sir George Bidwell Airy, astronomer royal of England, stated in an address before the British Association for the Advancement of Science, organized but the year before, that he did not know of the existence of a single public observatory within the confines of the United States of America. Sir George did not know of such an observatory for the very simple reason that none existed.

On December 6, 1825, John Quincy Adams, president of the United States, in his first annual message to Congress stated the following:

> Connected with the establishment of a university, or separate from it, might be undertaken the erection of an astronomical observatory, with provision for the support of an astronomer, to be in constant attendance of observation upon the phenomena of the heavens; and for the periodical publication of his observations. It is with no feeling of pride, as an American, that the remark may be made that, on the comparatively small territorial surface of Europe, there are existing upward of one hundred and thirty of these lighthouses of the skies; while throughout the whole American hemisphere there is not one. If we reflect a moment upon the discoveries which, in the last four centuries, have been made in the physical constitution of the universe by the means of these buildings, and of observers stationed in them, shall we doubt of their usefulness to every nation? And while scarcely a year passes over our heads without bringing some new astronomical discovery to light, which we must fain receive at second-hand from Europe, are we not cutting ourselves off from the means of returning light for light, while we have neither observatory nor observer upon our half of the globe, and the earth revolves in perpetual darkness to our unsearching eyes?

*Address at the mid-winter meeting on February 13 and 14, 1942, devoted to the Early History of Science and Learning in America, with especial reference to the part played by the American Philosophical Society.

The beginnings of astronomy in the United States started from practical necessities. For carrying on its business, each large city needed exact time, and this required good clocks and also telescopes fixed in the meridian to observe the transits of the heavenly bodies, the sun or the stars. As property in the virgin country gradually increased in monetary value it was natural that disputes should arise as to who owned what, with the result that boundary surveys became necessary. The most celebrated boundary dispute in the early years of the British colonies was between William Penn and Lord Baltimore. Everyone knows of the Mason and Dixon line between Pennsylvania and Maryland, Charles Mason and Jeremiah Dixon coming over from England in 1763. Although their work depended on astronomical observations they are usually referred to as surveyors and not as astronomers.

In my brief discussion today I shall confine the term astronomer to its very restricted meaning of research, namely, the process of acquiring of new information into fundamentals, and likewise I shall pay no attention to the many observatories erected for the practical uses of time or similar problems.

The first great American astronomer was David Rittenhouse. His life and work was in or near the city of Philadelphia. A half-century before President Adams spoke before the Congress of the United States, David Rittenhouse on February 24, 1775, delivered an "Oration" before the American Philosophical Society, the oldest learned society in the Western Hemisphere. According to the minutes of the society, the oration was delivered in the College of Philadelphia, (later called the University of Pennsylvania) "to a crowded audience, consisting of his Honor the Governor of the Province, the Assembly, and a great number of gentlemen of the first distinction, besides the members of the Society," Moreover, the oration was dedicated "To the delegates of the Thirteen Colonies, assembled in Congress at Philadelphia, to whom the future liberties, and consequently the virtue, improvement in science and happiness in America are intrusted."

To quote the words of Rittenhouse:

> Astronomy, like the Christian religion, if you will allow me the comparison, has a much greater influence on our knowledge in general, and perhaps on our

manners, too, than is commonly imagined. Though but few men are its particular votaries, yet the light it affords is universally diffused among us; and it is difficult for us to divest ourselves of its influence, . . .

You are all of you familiar with the fact that the American Philosophical Society was founded in the year 1743. A valued letter from Benjamin Franklin kept in the society's library gives the names of the nine original members, with himself as secretary. (In 1743, Franklin, the fifteenth of seventeen children, was thirty-seven years old.)

At a meeting held in the State House on February 2, 1768, we read in the minutes:

A Society having subsisted for some time in this City under the name of the American Society held at Philadelphia for promoting and propagating useful Knowledge, whose Views have been nearly the same with those which are published of the American Philosophical Society, and it being judged that the Ends proposed by both could be carried on with more advantage to the Public if a Union could take place between them, it is proposed that such a Union may take place.

Accordingly during the year 1768, the society took on a new lease of life and more than 100 members were elected.

Early in the following year, on Monday, January 2, 1769, the foremost citizen of Philadelphia, Benjamin Franklin, was elected president of the society, an office he continued to hold until his death in April, 1790. David Rittenhouse succeeded Franklin as president and he continued in office until his death in June, 1796.

Among the greatest names in all of the history of the United States are those of two illustrious men, Benjamin Franklin and Thomas Jefferson. In the family burying plot at Monticello is a monument inscribed:

> "Thomas Jefferson,
> Author of the Declaration of Independence of the United States, of the Statute of Virginia for Religious Freedom and Father of the University of Virginia."

As your speaker today has lived for more than twenty-five years in Virginia on Mount Jefferson in sight of Monticello, four miles distant, I hope you will pardon me for quoting from Mr. Jefferson's

letter in reply to notification that on January 6, 1797, he was elected president of the American Philosophical Society.

> I have duly received your favour of the 7th inst., informing me, that the American Philosophical Society have been pleased to name me their President. The suffrage of a body which comprehends whatever the American World has of distinction in Philosophy & Science in general, is the most flattering incident of my life, and that to which I am the most sensible. . . . Permit me to avail myself of this opportunity of expressing the sincere Grief I feel for the loss of our beloved Rittenhouse. Genius, Science, modesty, purity of morals, simplicity of manners, marked him one of Nature's best samples of the Perfection she can cover under the human form. Surely, no Society till ours, within the same compass of time, ever had to deplore the loss of two such members as Franklin & Rittenhouse. Franklin, our Patriarch, whom Philosophy and Philanthropy announced the first of men, and whose name will be like a star of the first magnitude in the firmament of heaven, when the memory of those who have surrounded & obscured him, will be lost in the Abyss of time.

Jefferson continued as president of the society during the eight years he was President of the United States. Late in the year 1808, when he was planning soon to move from the White House in Washington back to his home at Monticello, Jefferson tendered his resignation as president of the society. His resignation was not accepted and he continued in office until January 6, 1815. Franklin, Rittenhouse and Jefferson between them had been presidents of the American Philosophical Society from 1769 to 1815, a space of almost half a century.

The real cause of the awakening to life of the society in 1768 was literally a heaven-sent event, namely, a Transit of Venus that was most successfully observed in and near the city of Philadelphia and the genius who organized and carried the plans through to perfection was David Rittenhouse. The older members of the society have heard time and time again about Rittenhouse. To-day I wish to call briefly to the attention of the younger members and those who are not astronomers some of the high spots in the life of Rittenhouse, and at the same time to suggest to all of you that you go upstairs to the members' room and see for yourselves the astronomical clock and the transit telescope both made and used by Rittenhouse in his observations of the Transit of Venus on June 3, 1769. Also upstairs is a Dollond refractor that took part in the Transit of Venus observations and also

a theodolite that formerly belonged to William Penn and which was used for laying out the City of Philadelphia.

Rittenhouse was born on April 8, 1732, in a small stone house that now stands on the main drive through Fairmount Park. Even as a boy he showed extraordinary mathematical and mechanical ability and as he grew older he was always very resourceful in supplying his own needs. He acquired great proficiency in observational, practical and theoretical astronomy and in instrument making. The construction of his first telescope dates from 1756. His first observations as an astronomer were in 1763-64 when he carried out a survey for William Penn to settle the boundary dispute with Lord Baltimore. This boundary, between the present states of Pennsylvania and Maryland, was done with such high accuracy that it became part of the Mason and Dixon line.

His early fame rested primarily on the construction of his celebrated orrery of 1767, acquired by a college founded in New Jersey in 1746 and now known as Princeton University. This first orrery was lost, but a second one is now the proud possession of the University of Pennsylvania. For each of these instruments Rittenhouse received £300.

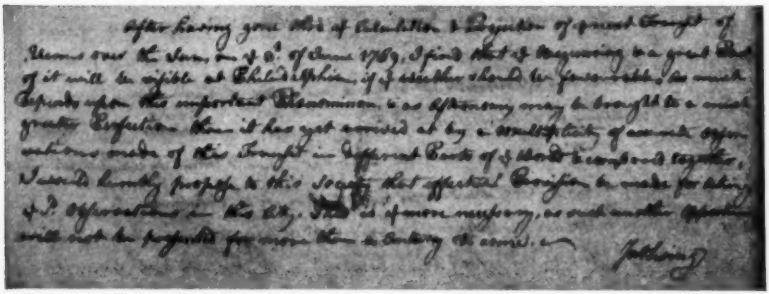
It is most interesting to read over the minutes of the society after its reorganization in 1768. At the meeting of March 8 held at the State House, "a fine of one shilling for non-attendance of members at meetings was ordered as a by-law of the Society. Six organic committees were then constituted by distributing the members present among the committees." At this early period in the life of the first learned society in the western hemisphere, rewards for attendance and penalties for non-attendance were put into effect. The minutes of succeeding meetings of the society furnish no information, however, regarding the amount the treasury's balance was enhanced by the one shilling fines.

At the very next meeting of the society (1768, March 22), Rittenhouse described his new orrery, and at the following meeting the committee on Rittenhouse's orrery reported that "they have the greatest Reason to expect from his known Abilities" that the orrery "will do honor to himself & to this Province, the place of his Nativity; and the Committee beg Leave to recommend it to the Society to order

his description to be published; not doubting but it will give Pleasure to Persons of a curious and Philosophical Turn." Hence the first paper ordered to be published by action of the society was one on astronomy, which then as now one and three-quarter centuries later had a strong popular appeal.

The description which appears as the first article in the first volume of the society's *Transactions* states that the orrery represents the motions of the sun, moon and planets, and therefore illustrates solar and lunar eclipses and other phenomena "for a period of 5000 years, either forward or backward." For showing the motions of the heavenly bodies it was the forerunner of the planetarium. Jefferson spoke of the orrery in these words: Rittenhouse "has indeed not made a world; but he has by imitation approached nearer its maker than any man who has lived from the creation to this day."

At the meeting of the society on April 19, 1768, John Ewing, later provost of the University of Pennsylvania, communicated a proposal in the following words, given here in facsimile and in type:



The 1769 Transit of Venus.

Extract from the minutes, April 19, 1768, of the American Philosophical Society for the Promotion of Useful Knowledge.

(After having gone through the calculation and projection of the next Transit of Venus over the sun, on the 3rd of June 1769, I find that the beginning and a great part of it will be visible at Philadelphia, if the weather should be favourable. As much depends on this important phenomenon, and as astronomy may be brought to a much greater perfection than it has yet arrived at by a multiplicity of accurate observations made of this Transit in different parts of the

world and compared together, I would humbly propose to this society that effectual provision be made for taking of the observations in this city. This is the more necessary, as such another opportunity will not be presented for more than a century to come.)

Accordingly plans were started to observe the transit from three separate sites, the State House square, the Rittenhouse farm at Norriton and Cape Henlopen. The society may well be proud of John Ewing. When he was provost of the University of Pennsylvania, he was likewise professor of natural philosophy, and it was said of him that "in the absence of any other professor, the Provost could take his place, at an hour's warning, and conduct the instruction appropriate to that Professorship with more skill, taste and advantage than the incumbent of the chair himself."

The condition at that time of the country surrounding the City of Brotherly Love may be surmised by reading from the minutes of the society that an inquiry was made "to know whether the Indians would allow proper Persons to pass through their Country in order to make the Transit of Venus observations." Perhaps the lives of the members of the expeditions sent out from this city were in no greater danger than were the lives of eclipse observers in the year 1900, for we have it on good authority that before crossing the Atlantic Ocean to witness the eclipse, the head of one of the British expeditions appealed to the United States Government to protect the lives of the party from the wild natives (sic) of North Carolina. I might add that on arriving in New York the fears were effectively dispelled when the party found themselves aboard a luxurious Pennsylvania train and discovered that they themselves, their baggage and their instruments were routed through to destination—and entirely free of charge. Of course this was in the good old days now gone forever!

Speaking to-day as one who has travelled to many quarters of the globe on astronomical expeditions, I know of the anxiety that grips the heart in the days before the great event as to whether you will be favoured by clear skies, or whether through no fault of your own you are to be doomed to bitter disappointment.

For the 1769 transit, widespread clouds were the general rule in the British Isles and in Western Europe, though in some places

observations were possible, but only through clouds and also with the sun at a low altitude. On the contrary, all three of the expeditions near Philadelphia had beautifully clear weather.

As already stated, Rittenhouse had a clock which he himself had made, a transit telescope also constructed by his own hands and now considered the first telescope made in America and a refracting telescope. These instruments are in the members' room upstairs.

The accuracy of the observations by Rittenhouse, who was assisted by William Smith and John Lukens, has been attested by Nevil Maskelyne, astronomer royal of England at the time, and by Simon Newcomb. The latter[1] states that "his observations of the celebrated transit of Venus in 1769 have every appearance of being among the best that were made." Combination with Greenwich results by a method improved by Rittenhouse gave 8."805 for the solar parallax, in remarkable agreement with the value 8."803, which has been the accepted value until a few months ago when the present astronomer royal of England, H. Spencer Jones, gave the refined value of 8."790, coming from observations made the world over on the planet Eros.

For carrying on the observations in Philadelphia the minutes read, "The Honorable House of Representatives had generously granted the privilege of erecting the Observatory in the State House Yard, and voted £100 for erection and observation to be paid to the Society Treasurer." Thus we see that the first observatory in the United States to be created at public expense dates from the year 1768.

In 1770, Rittenhouse moved to Philadelphia. His observations included transits of Mercury, solar and lunar eclipses, variable stars, the new planet Uranus (discovered by Herschel in 1781) and comets, including one discovered by himself in 1793. His work in astronomy was many-sided. To adjust instruments in the meridian, in 1785 he invented the collimating telescope, since then universally used. The same year he introduced spider threads into his telescope. In 1786 he made a plane transmission grating, thus anticipating Fraunhofer's grating by about 30 years. Newton had previously used "scratches made in polished plates of glass," but Rittenhouse measured grating intervals and deviations of several orders of spectra. He was fre-

[1]"Dictionary of American Biography," Vol. XV, page 630.

quently engaged in boundary surveys and commissions involving Pennsylvania, Delaware, Maryland, Virginia, New York, New Jersey and Massachusetts. Outside of astronomy, he served on the commission to organize the United States bank, and George Washington appointed him the first director of the Mint, on April 14, 1792, thus exemplifying the fact that a resourceful practical astronomer is equipped to tackle any job. At the University of Pennsylvania he was professor of astronomy and later trustee and vice-provost. In the American Philosophical Society he served as curator, librarian, secretary, vice-president and president. The highest of the many honors that came to him was his election, when president of our society, as a foreign member of the Royal Society. The first American to be so honoured after the Revolution was James Bowdoin, governor of Massachusetts and president of the American Academy of Arts and Sciences.

As an eclipse observer myself, I wish to direct your attention to the fact that only one week after the British evacuation of Philadelphia, "The first eclipse of the sun to be carefully observed[2] in the British colonies of America was that of June 24, 1778, which was watched by the astronomer, David Rittenhouse." Although the eclipse was total, with the gorgeous beauty of the corona readily visible to the naked eye, no mention was made in the record of Nature's most beautiful phenomenon. To us at the present day, one of the strangest portions of the history of astronomy before the middle of the nineteenth century is the evident lack of interest in, or perhaps one should say, the dearth of observations of the corona and of the rosy prominences visible without telescopic aid at the time of a total eclipse of the sun.

I must confess that I have constantly wondered why a keen observer like Rittenhouse had failed to describe the corona. Quite recently I came upon the explanation which I found in a first volume of the *Transactions of the American Philosophical Society*. This particular volume was the personal property of Dr. William Smith, provost of the College of Philadelphia. In his own handwriting he described the eclipse of 1778 which he observed with Rittenhouse,

[2]"Eclipses of the Sun," page 128.

but which unfortunately had clouds until long after the end of totality.

In the midst of the revolutionary war, in 1778, life in Philadelphia evidently went on about the same whether the British soldiers were present in the city or not. That was ages before we had heard of the word "schrecklichkeit" or of "the scorched earth."

The next total solar eclipse visible in the United States was only two years later, on October 27, 1780; it was not total in Philadelphia but was total in New England. This eclipse is memorable for two distinct features. It was the occasion of the first American eclipse expedition, under Professor Williams, of Harvard College. I think you will be interested in hearing some of the details from my own book, or as published in *Memoirs American Academy of Arts and Sciences,* vol. 1, p. 84, 1783. The account by Williams reads:

> Though involved in all the calamities and distresses of a severe war, the government discovered all the attention and readiness to promote the cause of science, which could have been expected in the most peaceable and prosperous times; and passed a resolve, directing the Board of War to fit out the Lincoln galley to convey me to Penobscot, or any other port at the eastward, with such assistants as I should judge necessary.

When the great day arrived, the Harvard party found itself outside the path of totality. However, an observation of great value was made, as you may learn from the following.

> The sun's limb became so small as to appear like a circular thread or rather like a very fine horn. Both the ends lost their acuteness and seemed to break off in the form of small drops or stars some of which were round and others of an oblong figure. They would separate for a small distance, some would appear to run together again and then diminish until the whole disappeared.

Here is a clear description of the eclipse phenomenon known to all of you as Baily's beads, as the result of observation by Francis Baily, a London stock-broker at the eclipse more than a half-century later, in 1836.

Another total eclipse of the sun, that of June 16, 1806, was again visible in Massachusetts but not in Philadelphia. This might be regarded as an instance of undue partiality to the rival scientific society in Boston, the American Academy of Arts and Sciences. However, I have been pleased to find that a member of the American

Philosophical Society, Andrew Ellicott by name, also described Baily's beads thirty years before the 1836 eclipse. The description I have never before seen published nor referred to. I found it in the "Manuscript Communications," Vol. 2, page 57, in a letter from Andrew Ellicott, part of which reads:

> Those detached luminous points of the sun's limb seemed to retain their brilliancy till the instant of their disappearance, which it would appear should not be the case, if the moon was surrounded with an atmosphere—those points particularly, which are formed by depression in the moon's limb would have had their splendour somewhat diminished by the density of the atmosphere, if one existed,—but nothing of the kind was observed.

In the same collection of manuscripts in the society's library, and four pages after Ellicott's letter I found another letter regarding the 1806 eclipse, this time from Simeon De Witt of Albany, N.Y., the contents of which pleased me mightily. The letter reads:

> With this I send you for the American Philosophical Society a painting intended to represent the central Eclipse of the Sun on the 16th of June last. It is executed by Mr. Ezra Ames, an eminent portrait painter of this place and gives I believe as true a representation of that grand and beautiful phenomenon as can be artificially expressed. The Edge of the moon was strongly illuminated and had the brilliancy of polished silver. No common colors could express this; I therefore directed it to be attempted as you will see by a raised silver rim which in a proper light produces tolerably well the intended effect.
>
> As no verbal description can give anything like a true Idea of this sublime spectacle with which man is so rarely gratified, I thought this painting would not be an unwelcome present to the Society or an improper article to be preserved among its collection of subjects for philosophic speculation.

A little more than a century later I myself was a Simeon De Witt and was instrumental in discovering another eminent portrait painter, Howard Russell Butler, who was with me in Oregon for the total eclipse of June 8, 1918. Again the artist and the astronomer engaged in team-work, as had been done for the eclipse of 1806, Mr. Butler in the ten days before the eclipse doing the difficult task of attempting by his skill as an artist to bring out the fire and the glory immediately surrounding the moon in the inner corona, the astronomer doing the easy task of criticizing as the result of experience gained at three previous total eclipses. Most of you have seen Mr. Butler's famous paintings of the eclipses of 1918, 1923 and 1925. For the first and third of these eclipses he was with me. He was near me at the 1923

eclipse but "unusually unusual" clouds in "beautiful sunny California" prevented him from being with me. The originals of the paintings form a triptych at the Hayden Planetarium of the American Museum of Natural History, and copies by Mr. Butler are in the Franklin Museum in this city and in the building of the National Academy of Sciences in Washington.

Andrew Ellicott (1754-1820) has been to me a most interesting character. He was of Dutch and English Quaker stock and belonged to the family that founded Ellicott City, Maryland. He was a mathematician and a surveyor and therefore an astronomer. In 1784, he was appointed member for Virginia for the group of surveyors that continued the Mason and Dixon line southward. In 1791, he began the survey, occupying two years, that gave the boundaries of the ten-mile square tract ceded by Maryland and Virginia as the site of the present District of Columbia. In 1811, Georgia invited him to run the line between that state and South Carolina. When the job was finished, Georgia refused to pay him more than his expenses for the simple reason that his line ran 18 miles farther south than Georgia's hopes. He appears to have had many stormy times in his career, but he found a haven of rest in 1813 at West Point, where he was professor of mathematics.

I have quoted from one of Ellicott's letters. Another was written from Lancaster, to Thomas Jefferson, president of the United States and of the American Philosophical Society, under date of December 29, 1801. Part of the letter reads:

> I enclose a few astronomical observations. . . . Being now the only native of the United States left, which time has not spunged (sic) away, and who has cultivated practical astronomy for the purpose of rendering it useful to commerce, to the division of territories, and the determination of the relative positions of the different parts of our own country, I feel a desire to keep the subject alive, till succeeded by some American, whose fortune may put it in his power to be more useful, by allowing him to devote his whole time to the improvement of so important a branch of science.

The observations referred to are chiefly lunar distances to check up on the lunar theory and to determine the longitude. From these and other letters, I have come to the conclusion that he had a fairly high opinion of his own importance and that he was at times a bit difficult

to get along with, perhaps a bit cantankerous. It has been said of him that "He had a happier hand with the theodolite than he had with the pen."

In spite of some shortcomings Ellicott was a most careful observer. At the eclipse of 1806 he determined the difference in longitude between Lancaster and Greenwich. The value obtained exceeded that derived earlier by 17 seconds of arc. He gave the correct explanation for this difference, namely, "imperfections in the lunar tables, which appear to give the moon's longitude at the time of the eclipse at least 1′ too much. The error in latitude at the same time is almost insensible." Also he correctly pointed out that by noting the northern and southern limits of the moon's shadow path on the earth, "observations were made for the express purpose of correcting the lunar tables." The most perfect results following this plan were at the total eclipse of January 24, 1925, when the southern edge of the moon's shadow was accurately determined at Riverside Drive in New York City. At the top of the apartment house at 96th street and south of the street the eclipse was not total, but north of the comparatively narrow street the corona was visible and the eclipse was total. The edge of the shadow of totality was, therefore, pinned down to within two hundred and twenty-five feet on the west edge of Manhattan Island.

Going back once more to the early minutes, we find the following, noted for the meeting of 1769, September 15. "Dr. Williamson delivered to the Society a paper in which he endeavoured to explain the theory of the motion of the Comets, the probability of their being inhabited, etc." This paper was referred to the Committee on Astronomy with instructions that they "publish it if they think proper without reporting." The publication appeared in *Trans.* (O.S.), vol. 1, 1771, appendix 27-36.

My audience to-day will smile at the apparently absurd idea that comets might ever be thought to be habitable. But let us stop a minute and look back. In 1715, the great Halley[3] thought that the appearances on the eastern and western edges of the sun at a total eclipse might reasonably be expected to be different, for the reason that "the eastern limb of the moon had been exposed to the sun's rays for a fortnight, and as a consequence it would be natural to expect

[3] *Phil. Trans.*, vol. 29, p. 248, 1715.

that the *heated lunar atmosphere* might exert some absorbing effect on the solar rays while on the contrary the western edge of the moon being in darkness and cold for two weeks could exhibit no such absorbing action." Of course we now know that the moon has no atmosphere. A half-century or more later, one of the greatest men in observational astronomy of all time, thought that the dark spots on the sun might be openings into the cooler portions of the sun that even might be habitable. To Herschel, astronomy owes the great reflecting telescopes, to him we owe the discovery of the planet Uranus, and to him and to his son Sir John we owe tremendous advances, particularly in stellar astronomy. Herschel's telescopes (judged by modern standards) were very crude affairs. It was not until 1817 that the art of glass-making had advanced enough to permit Fraünhofer to construct the "great Dorpat refractor," as it was called, with the then unprecedented aperture of 9½ inches.

This review of astronomy in the early years of the society would not be complete unless I called to your attention the enormous difference in an observatory then and now. At the present time an observatory may mean a 200-inch telescope and six millions of dollars. In the eighteenth century an observatory meant a structure costing a few hundred dollars, with a telescope small and crude, the telescope usually fixed in the meridian, chiefly to determine time and to assist in surveys of the virgin country. Most of these, like that on the State House Square, had a transitory existence. The first observatory belonging to a college was not erected near Philadelphia or New York or anywhere in the North, but south of the Mason and Dixon line. I have told you of the all-round ability of John Ewing, provost of the University of Pennsylvania. To illustrate the fact that Virginia never takes second place to any state in the Union (I should add that I am not a Virginian by birth) I would like to tell you a little about a contemporary of Jefferson, by the name of James Madison (1749-1812). At the age of 28 he became the president of the College of William and Mary, the second oldest college in the United States, and later he was the first bishop of the Protestant Episcopal Church in Virginia. In the year 1780 in November, he sent to Rittenhouse observations of the eclipse of Jupiter's satellites and the value of the longitude from Paris derived therefrom. In volume 3 of the *Transactions*, page 150,

reference is made to the "observatory" and to observations made of a lunar eclipse on November 2nd and of a Transit of Mercury on November 5, 1789.

The second observatory in this country was likewise not in the North but in the South, at the University of North Carolina. Joseph Caldwell was born in 1773 and graduated from Princeton when only 18 years old. At the age of 23 he went to Chapel Hill as professor of mathematics and at the age of 31 he became president of the university. In the year 1824 the trustees of the university had enough confidence in their president as to give him $6,600 and to send him to Europe to buy books and laboratory apparatus; the money spent was about equally divided between books and instruments. The equipment was chiefly astronomical and consisted in a meridian transit telescope, an altitude and azimuth telescope, a refracting telescope, a good clock with a mercurial pendulum, a sextant, a Hadley's quadrant and a portable reflecting circle. An observatory was built in 1830 and 1831, largely at President Caldwell's own expense. Its cost is given as $430.29½. Unfortunately, the construction was not very solid, and the roof leaked. After President Caldwell's death, the building deteriorated and it burned in 1838. The instruments, however, were saved. My friend, Dr. MacNider (of the University of North Carolina), writes me, "I wish so much you could see these beautiful old instruments. The brass is one of the softest, loveliest things in the form of a metal that I have ever looked at." Some of Sherman's soldiers on their march to the sea passed through Chapel Hill. They too admired the lovely finish of a telescope found on a dusty shelf in one of the laboratories. In picking up the telescope tube to examine it more closely, they found something loose inside, which turned out to be two gold watches placed by professors for safe keeping in the securest place imaginable. Needless to say, the watches were immediately appropriated. When the soldiers had left the laboratory, the professors returned to wind up their watches, only to find no trace of them. The loss was at once reported to the commanding officer. The story does not end there, and furnishes another triumph for the course of true love. It is said that the commandant was in love with the daughter of the president. The gold watches were promptly recovered and were returned to their rightful owners.

In the North, Yale University in 1830, secured a 5-inch Dolland refractor of 10 feet focus. There was no observatory. The telescope was pulled around in the Athenaeum Tower and pointed through one of the windows. Unfortunately, the windows were low and no object more than 30 degrees above the horizon could be observed. Similarly, Harvard College[4] possessed astronomical instruments from an early date but no astronomical observatory. Harvard College Observatory was established in October, 1839. The United States Naval Observatory was not started until 1844.

As might have been expected, astronomy, the so-called queen of the sciences, played a most important part in the early years of the American Philosophical Society for the Promotion of Useful Knowledge. And this was so, largely because astronomy more than any other science of 150 or 200 years ago was useful in the promotion of useful knowledge. To-day, when some of us can get along very well with a very inexpensive watch, we perhaps forget that before the days of the electric telegraph the only manner of ascertaining exact time was to make astronomical observations. Although exact time and topographic surveys were necessary as useful knowledge, the only astronomers whose names have lived throughout the two centuries are those who pursued knowledge for the useful purpose of gaining information about matters with no immediate practical application to business or to mundane affairs.

The history of astronomy of our society, revealed through manuscrips in our valuable library across the street, includes a few outstanding names of men who gained valuable knowledge regarding the distance to the sun or who progressed a step further toward solving Nature's secrets, through observations of eclipses of the sun or moon or of Jupiter's satellites.

[4]W. I. Milham, "Early American Observatories," *Popular Astronomy*, vol. 45, p. 523, 1937.

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DOES ANYTHING EVER HAPPEN ON THE MOON?

By WALTER A. HAAS

(*Continued from page 328*)

TYPES OF LUNAR CHANGES

We divide all lunar areas into 4 classes according to their intensity-variations:

Type I —Marks brighter at relative colongitude 90° than at r.c. 15° or at r.c. 165°.
Type II —Marks brighter at r.c. 15° than at r.c. 90° and brighter at r.c. 90° than at r.c. 165°.
Type III—Marks brighter at r.c. 165° than at r.c. 90° and brighter at r.c. 90° than at r.c. 15°.
Type IV—Marks brighter at r.c. 15° and at r.c. 165° than at r.c. 90°.

We purposely ignore the behaviour of marks before r.c. 15° and after r.c. 165° because extreme brightenings and darkenings frequently occur at those times. No distinction is made between bright areas (intensity 4.6 or greater) and dark ones (intensity 4.5 or less). Although two or more maxima in the interval r.c. 15°-165° are compatible with our definitions, it is unusual for more than one to exist.

INTENSITY-VARIATIONS OF LUNAR MARKS

The 131 marks studied comprise 30 dark areas on apparently level land, 13 central peaks or portions of central mountain-masses, 6 spots on isolated mountains or mountain ranges, 3 entire crater-floors, 2 sections of low ridges, 2 marks on a geological "fault," 1 valley-floor, 16 areas (11 bright and 5 dark) on east inner walls, 14 areas (8 bright and 6 dark) on west inner walls, 9 marks (5 bright and 4 dark) on south inner walls, 9 marks (6 bright and 3 dark) on north inner walls, 5 areas on west outer walls, 3 areas on east outer walls, 2 bright marks on south outer walls, 7 bright spots apparently not mountains nor craterlets and on level land, 6 marks in rays, and 3 sections of the *maria*. The manner in which the marks

studied were selected favoured those with unusually large ranges of intensity-variation, but it is thought that the sample taken is otherwise typical and is comprehensive enough to lead to correct conclusions.

The observed intensity-changes of a number of typical marks are given in Table VIII; those to which the numbers* refer will be identified later. Though given to the tenth of a unit, the intensities are probably usually internally reliable only to the third of a unit, the less certain figures being printed in italics; moreover, some of the values in the table evidently need correction but are intentionally left unchanged in order to enable the reader himself to judge the internal accuracy of my estimates. Each value given was, when possible, taken as the weighted mean (according to the conditions of observation) of two or more estimates. A short bar (—) in Table VIII means that no estimates were secured near that relative colongitude. The letter S indicates that the mark was in shadow at that time.

Changes of type I include most bright spots on level ground (mark 5 is a bright spot in the north part of Atlas, and mark 59 is one in the northeast part of Plinius); many central mountains (mark 67 is the northeast central peak of Theophilus); many bright spots and some dark areas on north and south inner walls (31 and 126 are bright spots on the north rim of Eratosthenes and on the south-southwest rim of Posidonius respectively, and 39 is a dark area on the south inner wall of Bullialdus); about one-quarter of the dark areas on level land (20 is a dark area in the east part of Manilius); probably many crater-floors considered as entities; perhaps some ridges; all rays (22 is the ray running due north from the north rim of Manilius, and 114 lies in one of the Tycho rays at a distance of about 100 miles from that crater); and the *maria* (mark 106 lies in Mare Imbrium just north of Pico). The intensity-maxima of the 39 marks in this class are: 12 very broad, 20 broad, 4 fairly sharp, and 3 sharp; these terms mean that the marks remained at greatest brightness for roughly 100, 50, 25, and 10 degrees of colongitude respectively. Many of the marks change much more rapidly during the first and last days in sunlight than at any other time, and the range of variation of most of them would be considerably reduced if one were to consider only the interval relative colongitude 15°-165°. The average range of variation of dark areas in this class is about 2 units; that of bright areas, $1\frac{3}{4}$ units, the difference perhaps being due to a scale-error. The maxima are distributed in r.c. as follows: 1 at 35°, 6 in the period 55°-65°, 7 at 75° or 80°, 11 at 85° or 90°, 8 in the interval 100°-110°, 5 at 125° or 130°, and 1 at 150°. The average time is seen to be almost exactly noon. Two of the marks may have secondary

*These I assigned to marks estimated for convenience in reference.

TABLE VIII.—TYPICAL INTENSITY-VARIATIONS

R.C. →	5°	10°	15°	25°	35°	45°	55°	65°	75°	85°	95°	105°	115°	125°	135°	145°	155°	165°	170°	175°
MARK																				
5	*5.8*	*5.4*	5.0	5.1	5.4	6.4	7.2	7.8	7.8	*8.9*	*8.3*	9.0	8.9	8.3	*7.0*	8.0	*7.0*	6.5	5.0	S
59	*S*	*5.0*	*5.0*	5.0	5.2	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.3	5.3	5.0	5.0	4.7	*S*	S
67	S	*5.1*	*5.1*	*5.0*	*5.3*	5.6	5.7	5.3	5.4	5.8	5.6	5.4	*5.4*	5.4	*5.4*	*5.3*	5.2	*4.9*	*5.0*	S
31	—	—	5.0	*5.3*	*5.3*	*5.7*	*5.7*	*5.8*	*5.8*	5.5	5.8	5.4	5.8	6.1	6.0	*5.0*	*5.0*	*5.0*	*5.0*	5.2
126	—	—	—	*7.2*	8.7	9.2	9.5	*9.8*	9.6	*9.4*	9.2	8.2	9.2	*9.4*	9.0	8.4	7.7	*7.2*	*7.2*	6.4
39	S	S	*1.0*	*1.5*	*2.5*	*2.9*	*2.9*	2.9	2.8	*3.5*	*3.4*	3.1	3.4	3.4	3.4	*4.0*	*4.0*	*1.3*	*0.5*	*0.5*
20	—	—	1.0	0.9	1.5	*2.5*	*2.7*	*2.7*	2.8	2.9	*3.0*	3.1	*3.4*	3.2	3.1	2.2	0.7	*0.5*	0.0	S
22	*2.0*	*4.0*	4.9	5.0	5.0	*5.0*	*5.1*	*5.1*	5.2	*5.0*	*5.0*	5.2	*5.0*	5.0	5.0	5.0	4.9	*4.9*	*4.9*	*3.4*
114	3.6	*4.4*	*4.9*	5.0	*5.0*	5.1	5.0	5.0	5.0	5.0	5.1	5.0	5.0	5.2	*4.8*	5.0	*4.8*	4.5	—	—
106	1.4	2.5	*3.4*	*3.4*	3.8	*3.4*	3.9	3.9	3.8	*3.7*	3.7	3.5	3.7	3.8	3.6	3.3	*3.2*	3.0	*1.8*	*1.8*
17	9.6	*9.5*	9.4	8.6	*8.0*	8.3	*8.3*	*7.7*	7.8	7.8	*7.5*	7.3	*6.2*	5.9	5.1	5.1	0.5	S	S	S
63	*7.5*	*7.3*	*7.0*	6.3	6.3	6.3	6.3	6.1	5.8	5.5	5.1	5.0	5.0	5.0	5.0	*4.5*	*S*	S	S	S
102	*2.0*	3.1	3.1	3.3	*4.0*	3.4	*3.4*	3.4	3.2	3.4	*3.4*	2.7	2.5	1.6	0.8	0.7	0.3	S	S	S
98	—	*5.4*	*5.2*	5.0	4.9	*4.9*	4.7	*4.9*	*4.9*	4.5	4.1	4.2	3.9	3.4	3.5	*3.7*	2.5	1.5	*0.5*	*0.5*
11	*10.0*	9.4	9.1	8.5	7.7	*7.7*	7.7	7.2	*7.0*	*7.0*	6.8	*7.0*	7.1	*6.8*	*6.5*	6.2	5.5	5.7	*6.0*	6.2
51	*3.0*	*3.5*	*3.8*	*3.3*	2.0	2.0	*2.2*	*2.3*	2.3	2.2	2.2	2.1	2.1	2.3	2.0	1.0	0.5	0.0	S	S
123	S	—	*3.0*	2.8	2.3	2.6	*2.0*	2.2	2.3	1.8	1.5	2.0	*2.0*	1.8	1.6	*2.0*	*1.6*	1.6	*1.2*	*1.2*
18	S	S	S	0.0	0.3	*0.0*	*1.0*	5.4	5.0	5.8	*6.1*	6.0	*6.1*	*6.4*	6.7	7.7	7.2	*8.0*	*8.6*	*9.1*
45	*2.0*	*2.0*	2.1	*3.7*	*3.7*	3.5	3.7	2.9	2.6	*3.0*	3.7	*3.5*	3.3	3.3	*3.5*	3.8	*3.5*	4.0	*5.7*	*5.8*
110	S	S	*3.4*	*3.1*	*4.9*	*4.9*	5.9	*5.8*	5.7	5.8	6.1	5.7	*5.4*	7.1	6.8	*8.5*	*6.6*	*7.0*	*7.0*	—
80	0.9	*1.2*	1.5	2.3	*2.0*	1.7	1.3	3.0	2.4	2.5	*2.3*	*2.3*	*2.3*	2.2	2.2	2.4	*3.4*	*3.4*	2.8	3.0
8	S	S	S	0.0	0.0	1.0	0.5	0.6	5.4	*5.4*	*5.8*	5.8	6.0	6.7	6.7	6.0	*8.9*	8.6	8.6	*9.0*
35	S	*S*	*4.0*	*4.0*	*4.0*	*2.5*	*2.0*	*2.0*	2.3	*2.4*	*2.4*	2.5	2.3	2.6	*3.4*	*3.4*	*3.4*	*3.1*	*3.1*	*4.0*
53	S	*4.0*	3.8	3.5	3.0	*2.5*	*2.5*	2.7	2.7	2.4	2.1	2.0	2.0	2.0	1.9	1.9	*2.5*	*3.5*	*3.5*	*S*
77	*1.3*	1.4	*1.4*	1.3	0.8	0.7	0.8	1.1	1.0	*1.0*	1.3	*1.0*	*1.4*	1.6	*1.8*	1.3	1.6	*2.0*	S	S
89	3.5	3.4	3.2	3.2	2.1	*2.0*	*2.0*	*2.0*	2.2	2.6	2.2	2.9	*3.0*	3.0	*3.0*	*3.0*	3.2	2.2	*1.8*	1.5
89A	3.5	3.4	3.2	3.0	1.9	*1.3*	*1.3*	*1.3*	1.7	2.3	1.8	2.0	*2.5*	2.2	*2.4*	*2.4*	2.0	1.4	*1.3*	1.2

N.B.—The numbers in italics are not so well determined as the others.

maxima near r.c. 0° or 180°. The behaviour just described is completely explained by assuming a surface pocked with relatively shallow and widely separated pits, the axes of which are mostly nearly perpendicular to the surface.

Variations of type II comprise all bright marks and probably most dark marks on east inner walls (marks 17 and 63 are bright spots on the southeast rim of Manilius and on the northeast inner wall of Plinius respectively, and 102 is a dark band on the east inner wall of Aristillus); most west outer walls (98 is the west outer wall of Eudoxus); west slopes of mountain ranges; some central mountains (11 is the northwest central peak of Theophilus); a few dark areas on level land and probably especially those near east walls (51 is a dark area in the east part of the floor of Eratosthenes); some bright spots and some dark areas on north and south inner walls (123 is a dark area on the south inner wall of Gassendi); perhaps some marks on north and south outer walls; and a few bright spots on level land. The portions of the preceding sentence outside of parentheses will describe changes of type III if *east* and *west* are interchanged. Marks in this class are: 18, a bright area on the west rim of Manilius; 45, the south tip of the Riccioli dark area; 110, a bright spot on the northeast outer wall of Eratosthenes; 80, the dark shading south of the bright spot at the northeast end of Pico; and 8, the south rim of Atlas. The maxima of the bright marks of type II are: 19 sharp at r.c. 0°, 2 fairly sharp at 0°, 2 fairly sharp at 10°, and 1 broad at 30°; those of type III bright areas are: 8 sharp at 180°, 4 fairly sharp at 180°, 1 sharp at 170°, and 1 very broad at 140°. The maxima of type II dark marks come out: 2 at 0°, 6 at 15°, and 2 at 25° or 30°, most of which are sharp or fairly sharp, and 2 very broad near 45°. The maxima of type III dark areas are: 2 sharp at 180°, 2 broad and 4 fairly sharp at 160° or 165°, and 1 very broad at 140°. The average maximum for dark marks is thus 20° in class II and 165° in class III. Four marks of type II (including mark 51) have secondary maxima near noon or after 150°, but perhaps these are due to imperfectly seen changing areas of types I and III in a portion of the marks. Bright marks change most rapidly before 20° in class II and after 160° in class III. For marks of type II the advent of shadow or pseudo-shadow in the late afternoon is preceded by rapid darkenings of the dark areas and by sudden great drops in intensity of the bright marks; bright marks of type III similarly show sudden rises just after pseudo-shadow is gone (note the behaviour of mark 8 near r.c. 70° in Table VIII). The average range of variation for both types is about 3½ units.

Changes of types II and III evidently differ only in position. The application to either of the theory derived previously leads to the scarcely acceptable condition of pits relatively deep and close together with axes usually horizontal for bright areas and usually tilted upward by 15° to 20° for dark areas. Since the position of the line of sight relative to the axes of the pits would be very important in determining the intensity-changes of marks pitted in this manner, their behaviour near the east limb would necessarily be very different from that near the west limb. Indeed, this result would follow for any sort of surface irregularities definitely arranged in any plausible manner with regard to a normal to the surface. Observations show that no appreciable difference exists. However, the very wide occurrence of marks of types II and III and the fact that

their brightness is obviously intimately related to the sun's position prove that their behaviour is due to the varying incident light.

Changes of type IV include about half of the dark areas on level land and some of those on inner or outer walls. A few bright spots *seem* to have intensity-minima near noon but perhaps only because of a combination of changes of type II on one slope and of type III on the opposite slope. Although such a list is necessarily *far from complete* for the entire moon, it appears worth while to enumerate dark areas found to be of type IV:

1. The north half of a dark area at the south end of Atlas.
2. The west part of the floor of Plinius.
3. The north part of the floor of Plinius.
4. The north end of the floor of Julius Caesar.
5. A dark area on the southeast inner wall of Eratosthenes.
6. A dark area in the east part of the floor of Bullialdus.
7. One in the northwest part of Bullialdus (mark 35).
8. One northwest of the central peaks of Eratosthenes (mark 53).
9. One in the north part of Gutenberg.
10. A dark area in the south part of Manilius.
11. The north end of a dark area northeast of Mount Bradley.
12. A dark area in the east part of the floor of Aristillus.
13. The floor of the craterlet Ptolemy A.
14. A dark spot at the foot of the southwest inner wall of Alphonsus.
15. A dark spot at the foot of the east inner wall of Alphonsus (mark 77).
16. A dark area at the foot of the north inner wall of Copernicus.
17. One in the south part of Vitello.
18. One on the Schickard floor in the south part of that crater (mark 89).
19. A dark area on the south inner wall of Schickard (mark 89A) and touching mark 89.
20. A dark area at the north end of Schickard.
21. One on the southwest outer wall of Eratosthenes.
22. The east outer wall of Tycho.

The average range of marks of type IV is about 1¾ units. The minima are mostly broad and fall in relative colongitude as follows: 3 at 50°, 4 at 60°, 2 at 70°, 3 at 80°, 8 at 90°, and 2 at 125°, the average being 80° and definitely before noon. Many of the marks show secondary minima at r.c. 0° or 180° or both and change rapidly before 15° and after 160°. We may also consider that such marks have two rather sharp maxima, one near 15° and one near 165°.

No kind of surface irregularities alone can account for a region's growing darker as the sun's elevation above it increases. Slipher met this difficulty by suggesting that the reported darkening is due merely to changing contrast with adjacent markings; [76] but, after 35 years of lunar observations, Pickering declared that the darkening is not possibly due to contrast only.[68] More than 1,000 hours of carefully planned and systematically executed observational

lunar studies have completely convinced me of the truth of the latter's opinion. If any marks on the moon represent *real changes*, as defined early in this paper, those of type IV do; and we may tentatively ascribe their behaviour to vegetation.

Irregular Intensity-Changes

In the course of analyzing the 4,241 estimates I found many large differences between estimates of the same mark near the same colongitude in different lunations. Most such deviations could be reasonably attributed to varying conditions, the use of different telescopes, rapid changes in intensity when the sun's position changed slightly, etc.; or else the estimates in question differed from others in the same lunation in a manner which showed that the former were erroneous. However, a residue of such deviations still remained and must represent varying behaviour in different lunations. There follows a list of the most probable examples of such irregular changes (the probable error of a single intensity-estimate is rarely more than half a unit):

1. In 1937 a dark band on the southeast inner wall of Aristarchus was observed to be intensity 0.5 on Spetember 28 at colongitude 191° but was called 2.5 on July 2 at 195° with conditions of observation identical. The band is *darkening* near colongitude 190°.

2. The west end of the central mountain-mass of Plinius was the subject of the following diverging pairs of estimates in 1937: 6.0 on July 20 at colongitude 53° but 8.5 on October 17 at 59°, 6.5 on July 22 at 78° but 8.5 on June 23 at 84°, 6.0 on September 22 at 114° but 8.5 on October 21 at 109°, and 5.0 on July 27 at 139° but 6.5 on September 24 at 142°.

3. The northwest central peak of Theophilus was brighter in June 1938 than in the next month.

4. In 1938 the east end of the Plato floor was called 2.0 on June 15 at colongitude 117° but 3.7 on July 15 at 123°, conditions being similar.

5. In 1938 the sunset brightening of the south tip of the Riccioli dark area occurred earlier in the July lunation than in the April and June ones.

6. In 1938 the Rocca coloured area already described was 1.0 on April 26 at 227° and 1.3 the next night at 239°, but it was 4.3 on July 24 at 235°.

7. In 1939 a dark area in the south part of Manilius was 2.0 on June 30 at 69° but 3.7 on July 30 at 76°. Conditions were very similar.

8. In 1939 a dark area in the east part of the Aristillus floor was 1.3 on September 23 at 25° and on July 6 at 143° but 3.7 on July 26 at 26° and 4.0 on September 3 at 144°; even the fact that different telescopes were used can hardly explain such great differences.

9. A dark area at the foot of the north inner wall of Copernicus was 4.8 on September 6, 1939, at 180° but 1.8 on July 9, 1939, at the same colongitude—a tremendous difference.

10. On September 25, 1939, at 50° the northwest central peak of Gassendi was called 9.4; but on August 27, 1939, at 56° it was estimated to be 6.4 under similar conditions.

11. In 1939 a dark area in the south part of Vitello was 2.5 on July 10 at 193° and 1.6 on July 11 at 205° but 4.0 on August 9 at 199°, conditions being similar on all three dates.

12. In 1940 a bright spot on the south rim of Maedler was 5.8 on September 16 at 82° but 8.9 on August 17 at 78°, conditions being similar.

13. In 1940 the northwest outer wall of Archimedes was 2.5 on June 20 at 88° but 5.0 on August 18 at the same colongitude.

14. The largest bright spot in the southwest part of the floor of Gassendi was 6.1 on September 18 at 107° and 6.7 the next day at 120° but 8.6 on August 20 at 113° and on July 22 at 119°, all estimates being made in 1940.

15. The northeast rim of Herodotus was 2 units brighter from 50° to 115° in June and July 1940 than over those colongitudes in August and September that year.

Since marks of all four classes are subject to these irregular changes, it appears likely that our earlier conclusions that changes of types I, II, and III are due solely to incident light may need to be modified.

The Moon's Atmosphere

The question of the existence and the nature of the moon's atmosphere is fundamental in the interpretation of lunar changes. We shall pass over the usual proofs of the *great tenuity* of the lunar atmosphere[74] and consider such observational evidence as appears to favour its reality.

Over a period of 9 years Schroeter saw very dim prolongations of the horns of the crescent moon into the earth-lit hemisphere, an appearance he ascribed to a lunar twilight in accord with the analogous aspect on atmosphere-enveloped Venus.[78] Schroeter's twilight was confirmed by Gruithuisen, denied by Beer and Maedler, suspected by Webb on one date, and seen by the Messrs. Henry at Paris with a large telescope.[78] Pickering described this twilight as *dimmer* than the earth-shine when the moon is crescentic (all others have made it *brighter* at that time) and as extending at first quarter a distance of about 60″ from each cusp.[48] In 1938 Johnson noticed in the course of other observations on the crescentic moon that the cusps were prolonged; the extensions, about 1″.5 wide,

were distinctly brighter than the rest of the earth-lit hemisphere but far dimmer than the sun-lit regions. On twelve dates in 1939-40 I looked for a twilight near the cusps; on eight of them nothing was seen, but on four others the rim of the earth-lit moon was brightest near the cusps. On the occasion of the clearest view (December 25, 1940, at colongitude 224°) each horn appeared prolonged by about 10 degrees. Vaughn saw definite prolongations on October 29, 1940, at 251°, the north horn being extended by about 15 degrees and the south one by from 5 to 10 degrees. Barcroft suspected similar prolongations near first quarter on March 6, 1941.

An appearance seen or suspected by no less than ten different observers over a period of 150 years and observed with many different telescopes is almost certainly real and at the very least merits careful study. This rather inconspicuous twilight is naturally seen best in a very clear sky.

The presence of many delicate winding rills, which he named "riverbeds," evidenced to Pickering the former action of water on the moon's surface and hence *at least the former* presence of an atmosphere.[43] With the exception of Schroeter's Valley, these "riverbeds" are too delicate to be studied with ordinary apertures in seeing not excellent.

At two occultations of Jupiter Pickering found by means of photographs that the disc of the planet was flattened by at most 0″.5 *in a direction perpendicular to the moon's limb.*[46,47] There was also detected, *both visually and photographically*, a dark band 3″ wide across the planet parallel to the moon's limb and immediately adjacent to it, this appearance being seen *only* when Jupiter was at the moon's *bright* limb.[47] Pickering ascribed the dark band to a layer of water vapour rising 4 miles above the moon's surface during the lunar *day*. These observations should be checked at future occultations of planets.

When a wide double star is occulted its components at a given moment are presumably subject to differing refractive displacements because the lunar atmosphere is not of the same density at their usually differing distances from the moon's limb. Observations of the occultation of Alcycone and its companion p on Oct. 13, 1897, G.M.T., led Pickering to conclude that the refractive

displacement at the *bright* limb is at most 0″.4.[48] Comstock announced on the basis of observations of 12 wide doubles that the displacement at the *dark* limb is at most 0″.2.[7] Computations from the latter's published data make the refractive displacement $-0''.06 \pm 0''.30$, and there is accordingly only about 1 chance in 10 that the shift exceeds 0″.50.

Pickering concluded that the surface density of the moon's atmosphere is about the same as the density of the earth's atmosphere at a height of 40 miles and is thus roughly 1/8000 the surface density of the latter atmosphere.[47, 48]

The observed temporary obscurations of detail in well-known regions favour the existence of a lunar atmosphere. Even if we ignore the imaginative Gruithuisen's fogs and clouds,[78] there still remain many examples attested by the most competent selenographers. Presumably many such observations have never appeared in print, but the list given by Goodacre deserves mention.[14] Some of his examples impress me as only ordinary changes with varying illumination, but others cannot reasonably be so dismissed. In his lunar papers Pickering frequently commented upon the lack of sharpness of some lunar detail at certain colongitudes, and he was inclined to attribute some of the Eratosthenes changes to shifting clouds.[67, 68]. The curious appearances, already described, in Plato and on the Tycho outer wall certainly look like lunar atmospheric effects.

In 1864 the Greenwich observers announced that the diameter of the moon as determined from occultations is 4″ less than that obtained by direct measurements.[48, 78] This difference may well be too great to be completely explained by irradiation, but the only conclusion we can here reach is that a star is displaced by *at most* 2″ at the moon's limb.

During a partial solar eclipse Spangenberg saw the dark edge of the moon *off the sun's disc*, as others have done at other eclipses.[77] If a lunar atmosphere were the cause, there would have been a thin luminous ring all around the moon; and this ring would have been seen best where projected against the less brilliant *outer* solar corona. Since Spangenberg saw the dark limb only against the brighter *inner* corona, we accept his conclusion that the corona and the very clear sky caused the appearance.[77]

The atmosphere of Venus causes a difference between predicted and observed half-phase on that planet.[78] In 1938 Johnson (on one date) and I (on two dates) looked for a similar effect on the moon. The difficulty of determining first quarter observationally precluded good results, and our work only establishes that the maximum possible difference between observed and predicted first quarters is 90 minutes.

The spectroscopic evidence[74] does not disprove the existence of a very thin atmosphere, for any lunar atmospheric lines would be concealed by far more intense terrestrial ones in the same positions. Hellweg, of the Naval Observatory, has kindly informed me that the maximum velocity of approach or recession of the moon relative to an observer on the earth's surface is 0.333 miles per second and that the corresponding Doppler shift of possible lunar lines is 0.01 angstrom unit with respect to a line at λ5800. Struve, of the Yerkes Observatory, wrote me: "With the existing spectrographs, it is indeed impossible to distinguish a faint spectral line, the centre of which is only 0.01 angstrom units from the centre of a more intense line."

Let us next consider briefly the theoretical possibility of a thin lunar atmosphere. A gaseous molecule with a velocity equalling or exceeding the velocity of escape from the moon, 2.38 km. per sec., will leave the moon forever unless acted upon by other molecules. Jeans has computed that if the mean-square velocity of the molecules of a gas is 1/3 the velocity of escape, then half of this gas will escape in a few weeks; if 1/4, in several thousand years; if 1/5, only in hundreds of millions of years.[74] In the following table v_0 denotes mean-square velocities at 0°C.; v_{100}, at 100°C., both being measured in km. per sec.

TABLE IX.—ESCAPE OF MOON'S ATMOSPHERE

Gas	v_0	v_{100}	$2.38/v_0$	$2.38/v_{100}$
Hydrogen	1.84	2.15	1.29	1.11
Helium	1.31	1.53	1.82	1.56
Water Vapour	0.62	0.72	3.84	3.30
Nitrogen	0.49	0.57	4.86	4.18
Oxygen	0.46	0.54	5.17	4.41
Carbon Dioxide	0.39	0.46	6.10	5.17

We see that if the moon originally had an atmosphere similar

to the earth's and if the temperature of our satellite has always been between 0°C. and 100°C., then we should expect to find there after hundreds of millions of years no hydrogen, helium, nor water vapour, traces of nitrogen, rather more oxygen, and almost all of the original supply of carbon dioxide. However, the temperature of preponderate importance in enabling molecules to escape is the *maximum* temperature attained; and if the moon has ever been very hot, it must quickly have lost its whole atmosphere. But as La Paz pointed out,[34] the proper temperature to use in all such calculations is that *near the top of the atmosphere*, a temperature almost certainly always far below 0°C. and thus favourable to the retention of an atmosphere. Our investigation is now halted by our ignorance of the origin, history, and age of the moon. Further, any results we could reach would be greatly modified by:

1. Chemical combinations the various gases might enter into.
2. The possible replenishing of the lunar atmosphere by gases escaping from the interior of the moon. Pickering alluded to this matter in a number of his papers, and the localized temporary obscurations already mentioned favour its actually happening.

One might expect that the very low temperatures prevalent during the lunar night[44] would congeal any gases on the moon's surface, but the extremely low pressures perhaps prevent such a condition. Precise calculations are hardly worth while until the night temperature of the moon and the surface pressure of its atmosphere are known with some accuracy.

The atmosphere of the moon is *far more homogeneous* than that of the earth (as a result of less gravitational force); whereas for the latter body a vertical ascent of $3\frac{1}{2}$ miles halves the density of the atmosphere, the corresponding distance for the former is 21 miles.[47] At some height above the surfaces of the two bodies the atmospheres are necessarily of equal density; below such a height the earth's is the denser, but above it, the moon's. The height of equal density has been computed by Pickering to be 53 miles[47] and by La Paz to be 45 miles.[34] The former estimated that lunar shooting stars first become luminous 210 miles above the moon's surface.[47] These figures all depend upon the uncertain surface density of the lunar atmosphere and are consequently not to be trusted too far; but it is interesting to note that the moon

may in reality be better protected from meteoric bombardment than is her primary.

On the basis of empirical evidence from the 1908 Siberian Fall and of theoretical considerations, La Paz concluded that meteorites with masses exceeding 10 pounds would produce upon striking a *completely airless* moon a flare visible to the unaided eye from the earth.[34] He estimated that there should be about 100 such flares annually on the earth-lit hemisphere and asserted that the fact that none have been recorded* is good evidence that the moon is protected by an atmosphere from impinging meteorites.[34] Unfortunately, the observational evidence about the absence of such flares* is unsatisfactory. Little attention has been given to the earth-lit hemisphere, and apparently the only *systematic* search for flares yet conducted is observations of the earth-shine totalling less than 20 hours carried on by La Paz in 1938 with a 4-inch refractor (he told me personally of this matter). Such searches might profitably be attempted with large telescopes and a very clear sky.

Let us inquire whether selenographers examining telescopically the *sunlit* moon can be expected to witness impact-flares *if* the moon is completely airless. La Paz's figure (100 flares annually) would be increased by the use of a telescope, decreased on the brilliant sunlit hemisphere, increased again if high magnifications are employed; we shall adopt it in order to be concrete. A hundred flares annually if randomly distributed mean a flare *somewhere* on the moon every 3.65 days or every 87.6 hours. However, a selenographer necessarily observes only a very small part of the moon at once; and flares located outside this region would escape his notice. Let R denote the radius of the moon and r the radius of the assumedly circular area the selenographer is studying. The area of the *illuminated* part of the *visible* hemisphere is $4\pi R^2/2 \cdot 2$ on the average, and the area of the region watched is πr^2 (ignoring foreshortening). There is thus observed $(r/R)^2$ of the sunlit and visible region. If $r = 54$, a value probably too large, the above ratio becomes $1/400$; and the selenographer must observe $87.6 \times 400 = 35{,}040$ hours to expect 1 flare. This figure means 35,040 hours of *careful observing through the eyepiece*, so that time

*But see the next section.

consumed at the telescope in recording notes and drawings must not be counted. An observer so extremely energetic as to average 200 hours a year of the required observing-time would have to work for $35{,}040/200 = 175.2$ years to expect to see a single flare. The preceding numbers are very uncertain but show that the failure to record flares on the sunlit moon is not surprising.

Of course, very large meteorites can produce impact-flares even on an atmosphere-retaining moon; but the figure of 100 a year would then be very greatly reduced.

Can shooting stars, fireballs, and meteor-trains in a possible lunar atmosphere be observed? It is known that the brightness of an object is decreased 1 stellar magnitude when its distance is increased $\sqrt{2.512} = 1.58$ times. Assuming that the limiting distance of visibility of a fourth-magnitude* meteor is 120 miles and solving for x in the equation:

$$1.58^x = 240{,}000/120 = 2{,}000,$$

we find

$$x = 16.6;$$

and conclude that the eye can not perceive a lunar meteor unless it is *at least* as luminous as those in our atmosphere of stellar magnitude $4 - 16.6 = -13$ (nearly enough). A telescope which under good conditions shows stars of the 13th magnitude can raise this figure to -6 *for a clear and dark sky* but in actuality probably only to -7 or -8 on the moon under the two most favourable circumstances, namely,

1. A totally eclipsed full moon.
2. The dark limb when a thin crescent is illuminated.

Fireballs of the necessary brilliance (-7 or brighter) are rare on the earth and presumably on the moon also; but systematic searches for lunar meteors by an experienced lunar observer at favourable times with a large telescope and a very clear sky are pre-eminently worth while.

We urgently request anyone who may witness unusual bright spots on the moon to submit detailed reports of such observations to Dr. Lincoln La Paz of the Ohio State University, the Director of the Ohio Section of the American Meteor Society, or to me. Lunar shooting stars are presumably most common near the

*Fainter meteors are not readily visible to the eye.

sunrise terminator; but fireballs and great meteorites might follow the opposite distribution, as is true of their terrestrial cousins.[11]

Recently Barcroft has kindly called to our attention several possible examples of impact-flares. These are so interesting and so little known that I shall report them in some detail.

Unusual Bright Spots on the Earth-lit Moon

1. *May 4, 1783.*[31] On this evening, when a Dr. Lind and his wife were visiting William Herschel at Datchet, a star was occulted at the dark limb of the moon. "Mrs. Lind . . . placed herself at a telescope and watched attentively. Scarcely had the star disappeared before Mrs. Lind thought she saw it again, and exclaimed that the star had gone in front of, and not behind the moon. This provoked a short astronomical lecture on the question, but still she could not credit it, because she *saw* differently. Finally Herschel stepped to the telescope, and in fact he saw a bright point on the dark disc of the moon, which he followed attentively. It became fainter and finally vanished."

Herschel was an experienced observer, and we may accordingly be fairly sure that he would not have considered an ordinary lunar bright spot unusual and that a seeming fading caused by atmospherical conditions growing worse would not have impressed him as real. The second sentence of the quoted section indicates strongly that the spot *appeared suddenly*, as an impact-flare would do. It is highly probable that at least 15 minutes elapsed from the time Mrs. Lind first saw the spot until it became invisible to Herschel.

2. *April 19 and 20, 1787.*[8] At 10:36* on April 19 Herschel saw on the earth-lit hemisphere 3 "volcanoes," the most marked one being 3′57″ from the "northern limb." (This statement is ambiguous. If he meant 3′57″ south of the northern cusp, the position would be near that of spots observed later by Schroeter and Grover. If he were viewing Aristarchus, he probably referred to the brilliant central mountain and not the whole crater, in view of a remark that "its diameter cannot be less than three seconds.") At 10:00* the next night the "volcano" appeared more brilliant. Herschel

*Probably local civil time.

compared it to a small piece of burning charcoal covered by a very thin coat of white ashes and seen in faint daylight.

Though perhaps no normal surface-feature, this spot enduring so long can hardly have been a flare.

3. *April 9, 10, and 11, 1788* (year uncertain). Schroeter saw a bright spot, resembling the next spot but less conspicuous, 26″ north of the rim of Aristarchus.[75] This mark was perhaps abnormal but was certainly no impact-flare.

4. *September 26, 1788.*[75] (The detailed reports on this spot and the next have been made possible by the courteous assistance of Mr. K. F. Guthe of the Harvard Observatory Library.) At 4.30 a.m.* on this date Schroeter remarked "a whitish bright spot, shining somewhat hazily and 4″ to 5″ in diameter" and as bright as a star of the fifth magnitude appears to the naked eye. Nothing similar could be seen elsewhere although detail on the earth-lit moon was very distinct and many familiar objects were recognized. The spot lay about 1′18″ southwest of Plato and in the bright mountainous region bounding Mare Imbrium. "But now my bright spot became inconspicuous at times, finally uncertain, and soon thereafter—it disappeared entirely."† It had been visible for fully 15 minutes. Schroeter emphasized the reality of the disappearance by declaring that Manilius and Menelaus were visible with equal distinctness before and after this event. He further stated that a drawing he had made of the region in question on October 2, 1787, did not show "the slightest trace of a bright spot." He was subsequently unable ever to recover this mark.[78]

This spot may well have been a flare and was almost certainly unusual.

5. *January 1, 1865.*[20] In a very clear sky Grover observed a bright spot at, or very close to, the position of Schroeter's second spot. Instantly reminding him of Herschel's idea of a glowing coal covered by ashes, the spot resembled a star of the fourth magnitude slightly out of focus. This bright speck remained changeless for fully 30 minutes, and its light was steady. In spite of the great similarity of this spot to Schroeter's the very infrequent visibility of any spot near their position appears to me to constitute conclusive evidence that two abnormal phenomena are involved.

*Probably local civil time. †Translation.

Grover himself spoke emphatically: "As to 'bright spots on the moon,' your correspondent 'Juvenis' is in error if he supposes my object was identification with a known object."

6. *August 12, 1902.* On this date G. S. Jones, using a 6-inch reflector at 250×, remarked at colongitude 18° on the dark side of the terminator and *probably* near Lambert a brilliant star-like point looking like a 3rd magnitude star and showing one diffraction-ring.[51] The point resolved itself into a very brilliant spot as the terminator approached it. Jones observed this mark for at least two hours, and it was consequently probably no impact-flare. Nevertheless, that it was probably unusual and is well worth searching for near colongitude 18° is suggested by several circumstances:

1. Lambert is a dull crater.[15, 51]
2. Pickering could not plausibly identify Jones' spot with either Lahire or Neison's Lambert T, two brilliant peaks in the vicinity.[51]
3. On October 10, 1892, near 18° Pickering could find no unusually brilliant spot near Lambert.[52]

Two of the three bright spots that may well have been impact-flares faded out *gradually*, and all three were visible 15 minutes or longer. Both circumstances suggest the blanketing effect of a lunar atmosphere, for on an airless moon the fused materials would radiate according to the fourth power of their absolute temperature and hence would soon cease to be luminous.

(*To be continued*)

REVIEW OF PUBLICATIONS

Star Maps for Beginners, by I. M. Levitt and Roy K. Marshall. Pages 34, 8½ x 11 in. Published by the Authors, Fels Planetarium, Philadelphia, Pa., 1942. Price 50 cents.

This useful little atlas consists of a ten-page introduction, twelve monthly star maps, and, for each map, a facing page giving a brief account of the objects for the month.

The introduction gives a very interesting survey of the development of the system of constellations from prehistoric to modern times, an explanation of the use of the maps, and a rough table for locating the four brightest planets for the next five years.

The monthly maps are of the horizon type. To avoid the customary distortion of this projection, the maps have been segmented into a roughly Maltese Cross shape. The centre of the cross is the zenith, and the four arms give the sky for the four points of the compass. While the distortion is reduced, the sacrifice of continuity in the north-east, south-east, etc., parts of the sky will seem to many users a rather heavy price to pay for this reduction. In the maps the stars are white stars on a black background. Stars to about the fourth magnitude are shown. Catch figures of the constellations are drawn in, and the brightest stars named.

The pages of descriptive matter give very concise, well-written stories of the mythology of the constellations, and in some cases a little astronomical information about objects in the region.

The book is bound in flexible cardboard, and will be a very informative addition to any beginner's library. The authors have, at the Fels Planetarium, had great experience in presenting such matters in a direct and interesting manner.

F. S. H.

Principles of Stellar Dynamics, by S. Chandrasekhar. Pp. 250, 6¾ x 9½ ins. Monograph published by University of Chicago Press. 1942. Price $5.00. Paper.

The last two decades have witnessed a great increase in our knowledge of the extent and general features of the galaxy and its

relation to the extragalactic nebulae. We now know or have a fair estimate of the distances, masses, rotations and velocities which exist among the various objects in the universe. The attempt to fit these phenomena into a mathematical model and from purely deductive reasoning harmonize them with observation is the domain of stellar dynamics.

The monograph treats of such problems as the orbits of stars within a stellar system, the intervals of time between collisions, the mean free path, the instability of such orbits, the formation of spirals and the rate of disintegration of star clusters. For each section a list of references is given chronologically which develops the problems from their first having arisen or gives reference to relative observational material.

The treatment is of necessity mathematical and principles underlying many problems are covered in the brief space of 250 pages, so that the ordinary reader must be prepared to do a great deal of outside reading to appreciate the text. The printing and paper have the usual excellent quality of the University of Chicago Press.

R. K. Y.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Observations of the 1942 Perseid Meteors

From Montreal Mr. DeLisle Garneau has sent us the results obtained during a very carefully planned and successful campaign for the observation of the Perseid meteors. While detailed analysis and publication of work of this kind will be postponed until the return of Dr. Millman from service in the R.C.A.F., a summary is presented herewith.

Mr. Edgar Guimont, working alone, observed and plotted the paths of 49 meteors on the night of August 11-12, and 15 on August 12-13.

At Ville Marie Observatory the Montreal Centre of the Society was represented by a party of six observers, a time-keeper and a recorder, and 240 meteors were observed and plotted on the night of August 11-12. Along with carefully prepared maps and record sheets, the recorder, Mr. A. V. Madge, included the following summary of this excellent night's work:

The 1942 Perseid shower was an unusually brilliant display. The radiant or point of origin in the sky, path of flight, colour, magnitude and time of appearance to the closest second of the two hundred and forty meteors observed during the Perseid observational program organized by the Montreal Centre of the Royal Astronomical Society of Canada, were recorded on the meteor record charts. The absence of the moon, together with excellent visibility, permitted the recording of the "August Shooting Stars" at a rate of sixty-four per hour or, considering the total observation time, at an average of over one meteor per minute. This is well above the average number of meteors seen during the maximum period of this well known shower.

Observations were made at the Ville Marie observatory in Montreal. The observers taking part in the progress being: H. F. Hall, secretary of the Centre; F. J. DeKinder, treasurer; Edouard Garneau, R. Duffie, Miss I. Williamson and Miss Guy. A. V. Madge and DeLisle Garneau acted as recorder and time-keeper respectively.

The equipment used during such a program is quite simple; no optical assistance being necessary. The equipment employed this year included: a watch corrected as to time, a stop-watch, a metronome set to beat once each second, meteor record sheets, Perseid charts and flashlights capped to prevent glare from white light.

The meteors observed were of the typical Perseid characteristics. Fast

moving, white in colour and ranging in magnitude from brilliancy of the planet Venus, to that of the faintest star visible to the naked eye. A number of the meteors observed left trains in the sky of from one-half second to six seconds. Several non-Perseids were recorded during the night.

As in former years, a group of observers comprised of Boy Scouts was organized under the direction of E. Russell Paterson, member of the council of the Montreal Centre, who has always taken an interest in having the Scouts assist in meteor observational work. Results of the work accomplished by these groups of observers will be sent to the David Dunlap Observatory for further study.

Thoreau's Rainbows

The statement made by Thoreau that on one occasion he stood within a rainbow is familiar to his many admirers—and also to some detractors. It is found in *Walden* in the chapter headed "Baker Farm", and was the subject of a brief discussion by the present writer in this Journal, July-August number, 1935. It may be quoted again:

> Once it chanced that I stood in the very abutment of a rainbow's arch, which filled the lower stratum of the atmosphere, tinging the grass and leaves around, and dazzling me as if I looked through coloured crystal. It was a lake of rainbow light, in which, for a short while, I lived like a dolphin. If it had lasted longer it might have tinged my employments and life.

The details of the observation recorded here should not be taken too seriously by the precise physicist. There is much that is fanciful and imaginative in the narative which indeed served Thoreau chiefly as a suitable framework on which to tack the ideas contained in the last two sentences. Thoreau was hardly an exact scientist, rather a student of nature and above all a philosopher.

Recently upon re-reading *A Yankee in Canada* the writer renewed his acquaintance with another description of a rainbow. In the latter part of September 1850 Thoreau and his friend Channing were members of a large excursion from Boston to Montreal and thence to the city of Quebec. After some days in the latter, they walked down to Ste. Anne de Beaupre and back. Then, on October 1, they drove in a calèche to the dock and onto the ferry ("inconvenient and dirty") which carried them across a mile of rough water to Levis on the south shore. The mouth of the Chaudière river is a few miles west from here and three miles up the stream is a splendid waterfall. It is pictured in *Canadian Scenery* (Bartlett and Willis, 1842), wherein it

is stated that the river here is 250 yards wide and the falls 100 feet high. They are used now to produce electric power.

Thoreau was much impressed with the view and in the course of his account of the trip he says:

> I saw here the most brilliant rainbow that I ever imagined. It was across the stream below the precipice, formed on the mist which the tremendous fall produced and I stood on a level with the keystone of the arch. It was not a few faint prismatic colours merely, but a full semicircle, only four or five rods in diameter, though as wide as usual, so intensely bright as to pain the eye, and apparently as substantial as an arch of stone. It changed its position and colours as we moved, and was the brighter because the sun shone so clearly and the mist was so thick. Evidently a picture painted on mist for the men and animals that came to the falls to look at; but for what special purpose beyond this, I know not.—Riverside Edition of 1887, p. 66.

Now the precise physicist can fairly criticise almost every phrase in this description as loose and inaccurate, but it was not for such persons that Thoreau wrote. To the ordinary reader there is presented a realistic and thrilling picture. Moreover it gives an opportunity for the remark "tossed off" in the last sentence, which is far removed from physical science.

Reference however will be made here to one feature. Thoreau states that "he stood on a level with the keystone of the arch"—that is, his eye was on this level—and the bow was on the mist at the far side of the chasm. From the way in which the rainbow is produced we know that the radius of the arc is about 41°, and consequently the centre of the arc must have been 41° below the "keystone". Now a straight line from the sun through the observer's eye passes through the centre of the arc. Hence the sun's elevation was 41°. On October 1 the sun is about 2° 51′ south of the celestial equator and the latitude of the waterfall is about 46° 48′. An easy calculation shows that on the given date the sun's elevation at noon, when of course it is greatest, was 38°, while at 2 p.m. it was 32° and at 3 p.m. 27°. The hour of the day is not stated but it was well on in the afternoon as they were too late for the last ferry to Quebec and had to stay in Levis over night. This shows that Thoreau's observation was only a rough approximation.

It is not for his contributions to science that Thoreau is held in high regard, and his social theories will not stand a very close examination. He was a real lover of nature, both human and other-

wise, and his acute observations on men and other matters are always arresting and thought-provoking. His chief business seems to be to philosophize, and the lurking mysticism and the touch of genius and inspiration, felt everywhere but hardly analysable, will ensure him enthusiastic disciples for decades to come. Thoreau died in 1862, aged 45. C. A. C.

Errata—"It never rains but it pours!"

Readers of Mr. Wates' interesting article in the September issue will have noticed that pages 305 and 306 had been interchanged. On page 301 of the same article the word "except" was omitted after "meaning" in the second line from the bottom. Also, the last three lines of page 342 should have been inserted between the second and third lines from the bottom on page 343.

MEETINGS OF THE SOCIETY

AT TORONTO

February 17, 1942.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Dr. D. W. Best in the chair.

Six persons were duly elected to membership in the Society, viz.:

Willard T. Burgoon, Royal York Cres., Humberside P.O., Toronto;
F. Currie, 102 Mimico Ave., Mimico, Toronto;
Donald Crawford, 248 Torrens Avenue, Toronto;
Rev. T. Christie Innes, 407 Brunswick Avenue, Toronto;
Gordon James Lyon, 266 Douglas Drive, Toronto;
Thomas A. Matthews, 37 Oriole Road, Toronto.

Dr. Best referred to the recent death of Dr. Frank S. Hogg's mother and the meeting instructed the Secretary to send a letter of sympathy on behalf of the members.

Rev. T. Christie Innes, M.A., of Knox Presbyterian Church, Toronto, was introduced by Mr. J. R. Collins. He addressed the meeting on "Biblical Astronomy." "Heathen peoples have always worshipped the sun, moon, stars and unseen powers of Nature as gods," Mr. Innes said. "But while the Hebrew writers were keenly interested in, and reflectively observant of, all Nature, they viewed the whole universe as the creation of one God. To them the inexpressibly glorious works of Nature had no power or vitality of their own, but the whole universe was an ordered system regulated by a divine power. The purpose of the Bible is not primarily to demonstrate the relation of one thing to another—that is the function of Science—but to reveal and relate God to mankind. Yet, although it is not the purpose of Scripture to teach science, incidental Biblical references to what we call scientific fact are remarkably exact, sometimes even in advance of scientific discovery."

"Astronomy, the study of observed facts about the stellar universe, was, according to Martin Luther, 'the most ancient of all sciences and the introducer of vast knowledge'," Mr. Innes said, but Luther's estimate of Astrology was 'tis nothing'. "Astrology, a system of guesswork based on the supposed influence of the stars, is a perverted deduction of astronomy," he added. "It is amusing to recall that Cardan, the celebrated astrologer of the 16th century who hated Luther, actually changed his birthday in order to give him an unfavourable horoscope. It may be of interest to observe the Biblical estimation of astrology. The ancient Assyrians and Babylonians left many tablets which refer to its practice, and observations and omens were used for several thousand years. Yet, astrology is an unwarranted and unfounded prying into the august future which no man can foretell. Heathen astrologers 'consulted' stars, drew horoscopes and predicted lucky (?) days with universal approval and their statements were accepted as 'scientific'. Recently a widely-read weekly paper told us that 'Astrology, a favorite pastime of the Middle Ages, is enjoying to-day a second childhood'. The writers of the Bible, however, universally classed astrologers

as 'abominations', and Israel was exhorted, in contrast with them, to be sincere and upright (Deut. 18. 10-14). Because the masses of his day implicitly believed these prognostications in the most solemn fashion, the great statesman preacher Isaiah conveyed his tremendous challenge to Babylonia: 'Go on with your spells! Practise your magic arts! . . . You have worn yourself out with them all. Let the astrologers come forward now. Let the star-gazers save you now who calculate the future month by month' (Isa. 47. 12-15). Luther agreed with Isaiah that 'to believe in the (effects of the) stars, or to trust thereon, or to be affrighted thereat, is idolatry and against the first commandment'."

"Turning to astronomy we find many scientific statements in the Bible," the speaker said. "It is interesting to note that Genesis follows the order of science when it introduces matter (earth); darkness, motion (moved), light and heat (lights, one of which was the sun), in that sequence. Sir William Dawson said: 'We have here a consistent scheme of the development of the solar system, and especially of the earth, agreeing in the main with the results of modern astronomy and geology. It would not be easy even now to construct a statement of the development of the world in popular terms so concise and so accurate.' Sir James Jeans said: "These concepts reduce the whole universe to a world of light, potential or existent, so that the whole story of its creation can be told with perfect accuracy and completeness in the six words—God said, 'let there be light'."

Mr. Innes referred to two Biblical passages of astronomical interest, Job 38 and Psalm 8. "It is in Job that we get most astronomical sidelights," he said. "The idea that the earth was flat was rather one of the Middle Ages than of the Hebrews. There are no actual original manuscripts of the books of Scripture. But we have thousands of translations and quotations in which we must try to determine as nearly as possible what the original meaning was as many phrases have suffered in translation and re-translation. Sometimes the marginal notes in our Bibles are more correct than the text itself. For instance, 'firmament' suggests something solid, but the original Hebrew 'raqia' meant 'stretched out' or 'expanse'. It was inaccurately translated in Greek and then translated into Latin. In Job 26.7 we find 'He stretcheth out the north over the empty place and hangeth the earth upon nothing.' Is this an early statement of Newton's law of gravitation? An all-surrounding ether may be suggested. Professor E. E. Barnard actually discovered a huge area in the northern heavens without a single star in it. Did Job know of it too when he spoke of 'the empty place?' Deborah (Judges 5.20) sang that 'the stars in their courses fought against Sisera.' Possibly the fact that planets and stars have motion was common knowledge then as now? Unfortunately the Old Testament is limited to the few-worded and inflexible Hebrew. The astronomer Schiaparelli collected all Biblical references to astronomy and attempted to draw up a picture of the Hebrew idea of the universe but the result, indicating they believed the stars were holes in a box-like firmament, was very childish. We must keep clearly before us that we have only passing references and not enough to rebuild the Hebrew system of astronomy."

Dr. Helen S. Hogg then presented the seventh in the series of papers on "Explorations in Clusters and Nebulae," dealing with the extragalactic nebulae. Several hundred of these misty patches, which under high magnification resolve into independent stellar systems in inter-galactic space comparable with our Milky Way system, were known early in the 19th century. A bright nova was observed in the Great Andromeda Nebula in 1885, the first individual star ever seen in an extragalactic nebula, but it was not until 1924 that parts of these objects were resolved into stars with the 100-inch telescope at Mount Wilson and their relative distances determined. The faintest identified so far is about 500 million light-years distant. It is estimated that at least 100 million would be observable to this limit were it not for obscuring matter in space. Two of these nebulae are as close as 100,000 light-years. All of the same order of intrinsic luminosity, they average about 85 million times that of the sun. Although the 16th century philosopher Immanuel Kant brought in the idea of "island universes" it has only been in the last half-century that astronomers had anything to back it up, Dr. Hogg said. "The history of astronomy is essentially one of receding horizons," she added.

With the single exception of M31, the Great Andromeda Nebula, none of the extragalactic nebulae are visible to the unaided eye in the northern hemisphere although these small, symmetrical objects are found in great abundance everywhere in the sky except in the central region of the Milky Way where they are probably concealed by a dark cloud of obscuring material. They are grouped in an ordered sequence from globular nebulae through flattening, ellipsoidal figures, to a series of unwinding spirals. Rotational symmetry changes through the sequence and suggests an increasing speed of rotation in the various types from globular down to open spirals. Luminosity remains fairly constant but diameters increase from 1800 light-years for globular nebulae to more than 10,000 light-years for open spirals. Masses are difficult to determine but are estimated to range from 2×10^9 to 2×10^{11} that of the sun. The extragalactic nebulae are scattered at average intervals of two million light-years through space, a pattern similar to tennis balls placed 50 feet apart. If nebular material were spread out through the entire observable region of space, the density of matter would be one grain of sand per volume of space equal to the size of the earth.

About one-fifth of these nebulae are of elliptical type, ranging from globular to ellipsoidal figures with a limit of 3:1 for the axes ratio. These cannot be resolved into stars. Most of the remainder are spiral type or the normal or barred varieties. The first class of normal spirals show a large nuclear region of unresolved nebulosity with arms closely coiled and unresolved. As the sequence progresses the arms unwind and condensations appear and part of the nucleus can be resolved into stars. In the early stage barred spirals there is a broad bar condensed diametrically across the nucleus from rim to rim, while in later stages a ring breaks from the bar at two points and spiral arms grow out of the broken ring. Two or three per cent. of the extragalactic nebulae are classed as irregular. They have no conspicuous nuclei, and, as their stellar

contents are like that of late-type spirals, they may possibly be a last stage in the sequence of regular nebular development. The Magellanic Clouds are classed among these irregular nebulae.

FREDERIC L. TROYER, *Recorder.*

March 3, 1942.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Dr. D. W. Best in the chair.

Two persons were duly elected to membership in the Society, viz.:

G. H. Mallory, 83 Cameron Crescent, Leaside, Toronto;

H. C. Hooper, 77 York Street, Toronto.

Miss Edna M. Fuller, librarian of the David Dunlap Observatory, then addressed the Society on "Recent Astronomical Books." Books were important in maintaining morale in wartime, Miss Fuller pointed out. "It is fortunate that publishers on this continent have not been seriously affected by paper shortage and other factors which have so reduced the output of new books in Britain that librarians are becoming worried about the situation," she said. Miss Fuller referred briefly to the newer books on astronomy and allied sciences, and to books on the history of astronomy and biography of astronomers. She especially mentioned the four volumes already published in the new series of Harvard Books on Astronomy by members of the staff at Harvard Observatory.

Dr. Helen S. Hogg followed with the eighth in her series on "Explorations in Clusters and Nebulae." Speaking on the "local group of galaxies" she referred to the systems which are regarded as companions of our stellar galaxy—the Magellanic Clouds, Sculptor and Fornax clusters, the Great Andromeda Nebula (M31) with its two companions, and others. "In the realm of recent discoveries it is pleasant to think that in our gigantic universe we are not alone," Dr. Hogg said. "These other nearby galaxies seem to form a physical group related in some way to our own stellar system." There was also the possibility, she said, that some of the globular clusters, now considered part of the stellar system, may be independent extragalactic systems.

The Magellanic Clouds in Doradus and Toucan, nebulae of the irregular type, are remarkably similar in content to our galactic system, and have gaseous nebulae, globular clusters, and thousands of variable stars. Novae are very scarce. The Large Magellanic Cloud contains the most luminous star known—S Doradus, which has a radiation output about 300,000 times that of the sun. The Magellanic Clouds are so near that they might be regarded as pieces broken from the Milky Way, and yet so distant (about 85,000 and 95,000 light-years respectively) that they must be classed as separate systems.

The Sculptor cluster (250,000 light-years distant) and the Fornax cluster (550,000 l.y.) resemble enormous globular clusters comparable in size to a galaxy. The former covers an area of more than a degree, yet their light is so faint that neither was discovered until about five years ago. Another of the close objects is NGC 6822 in Sagittarius, a faint dwarf irregular nebula with Cepheid variables, globular clusters and nebulosity.

The Great Nebula in Andromeda (M31), the only extragalactic object visible to the naked eye of observers in the northern hemisphere, is a typical

spiral with a large unresolved nuclear region and fainter arms in which many novae and Cepheids have been observed. About 140 globular clusters have been catalogued in it. This nebula is the chief component of a triple system which also includes M32, a highly concentrated nebula which has never been resolved into stars, and NGC 205, an abnormal dwarf elliptical nebula in which few stars appear. These objects are all about 680,000 light-years distant, and M31 is of the order of 40,000 l.y. in diameter. Other objects associated with our stellar galaxy are M33, a massive spiral in Triangulum with spiral arms which have been highly resolved into stars, clusters, Cepheids, novae and a few globular clusters, and IC 1613, a small faint irregular nebula in Pisces with many Cepheids.

FREDERIC L. TROYER, *Recorder.*

March 17, 1942.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Dr. D. W. Best in the chair.

Three persons were duly elected to membership in the Society, viz:

Miss Helen E. Curwood, 141 Christie Street, Toronto.
Mr. A. Douglas Smith, 41 Hayden Street, Toronto.
Mr. Arthur A. Bulbeck, 41 Hayden Street, Toronto.

Dr. C. A. Chant, Director Emeritus of the David Dunlap Observatory, then addressed the Society on "The Magnitudes of the Stars". As a subtitle he added the biblical quotation, "One star differeth from another star in glory". Another translation of the last word, said he, is splendour. They are both very appropriate in describing a naked-eye view of stars and planets spread along the sky. These words, *glory* and *splendour,* denote abstract qualities and it seems unnatural to apply numbers to measure them. Two ancient astronomers are of special interest to us in discussing this subject—Hipparchus and Ptolemy. The former had an observatory on the island of Rhodes about 150 B.C. He was a very able man, comparable to Galileo, Newton or Kelvin, and used the term *magnitude* in describing the stars in a list he made. That word usually means bulk or size, but not so here. It is the brightness of the stars which is referred to and has nothing to do with bigness. No original writings of Hipparchus have come down to us, but information regarding him is given by Pliny, who lost his life in the destruction of Pompeii in 76 A.D.

Claudius Ptolemy made observations at Alexandria between the years 127 and 151 A.D. He was a true follower of Hipparchus, and his great treatise, usually called "The Almagest", is extant in Greek, Latin and Arabic. Both Hipparchus and Ptolemy arranged the stars in six magnitudes. Why six? Those stars which can just be seen on a clear dark night are assigned to magnitude 6, and according to increasing brightness the rest are put in magnitudes 5, 4, 3, 2 and 1, the last class including about 20 of the brightest stars. Each magnitude seemed to be quite distinct from the next one. Indeed Ptolemy, by adding letters signifying greater or less indicated a brightness somewhat above

or below the clear-cut six magnitudes. Ptolemy does not state why six magnitudes were chosen, but they have persisted through the centuries.

By means of a set of tuning forks Dr. Chant illustrated the major diatonic scale, well known in music,—

do, re, mi, fa, sol, la, si, do'.

The first and last notes, *do* and *do'*, are said to be an octave apart, and when sounded together, or one after the other, give perfect harmony; and the other six notes are so spaced between them that the series gives the greatest pleasure to the listener. It is a matter wholly determined by the cultivated ear. However when we determine experimentally the number of vibrations per second (i.e., the frequency) of each note we find that the frequency of *do'* is exactly twice that of *do*, and the interval between them is denoted by 2/1. The note *sol*, which harmonizes well with *do*, has a frequency 1½ that of *do*, and the interval between them is 3/2. The notes of the scale are definitely determined by fixed numerical ratios, and the smaller the numbers which express the intervals—2/1. 3/2, 4/3, etc.,—the more perfect is the harmony. Were the stars arranged in six magnitudes because they gave the most pleasing sequence of brightnesses to the eye? Perhaps so, but there is not enough evidence to give a positive answer.

Tycho Brahe (d. 1601) was the last great astronomer to observe without a telescope; but when that instrument came to be used, fainter stars were revealed and magnitudes bearing larger numbers than 6 had to be employed. William Herschel used higher numbers than some other observers, and the whole question became a live one. It was necessary to settle the principle on which the numbers were to be assigned. About 1830 John Herschel, from actual measurement, showed that a star of magnitude 1 was approximately 100 times as bright as one of magnitude 6; and he expressed the view that the brightnesses of the succeeding magnitudes should be arranged in geometrical progression. These statements did not receive much consideration at the time. A few years later photometric measurements showed that the brightness of a star of a certain magnitude (for instance 3) was approximately 2½ times that of one a magnitude fainter (for instance 4), and at the suggestion of Pogson in 1850 it was agreed that this ratio be fixed at 2½—or rather at a number whose logarithm was 0.4. This was done without any reference to the ratio of 100 to 1 between a 1st and 6th mag. star, which is now looked on as the fundamental relation. The light-ratio between two stars which differ by one magnitude is 2.512, but for ordinary calculations 2½ is amply accurate. A star of mag. 1 is 2½ times as bright as one of mag. 2, which is 2½ times as bright as one of mag. 3, and so on. For a difference of five magnitudes the ratio between the brightnesses is 100. Now the faintest stars which can be photographed by the 100-inch Mount Wilson telescope are of mag. 21. Between this and mag. 1 there are 20 magnitudes, or five magnitudes taken four times. Hence the light-ratio between a 1st and a 21st mag. star is $100\times100\times100\times100$, or 100 million.

Suppose we are given two sources of light (or lamps), one of 1 c.p., the other of 100 c.p., and are asked to secure four other lamps which will appear to the eye to be spaced at equal intervals between them, that is, the six lamps will appear to rise in brightness by uniform steps. This is an experiment in practical optics which with patience and care can be performed. But let us look at it theoretically first.

We can find a series of values between 1 and 100 which will rise by equal steps from the first to the last. Such a series is

1, 20.8, 40.6, 60.4, 80.2, 100,

in which the terms increase by the constant difference 19.8. Such a series is called an arithmetical progression. But we can calculate a series such as

1, 2½, 6¼, 16, 40, 100,

in which each term is 2½ times the term before it, or the constant ratio is 2½. This is a geometrical progression. A series of lamps with candlepowers equal to these numbers will appear to increase in brightness by equal steps. It is on this geometrical progression principle that the brightnesses of the stars are arranged in magnitudes.

Argelander (1799-1875) at Bonn, on the Rhine, used a telescope of aperture 34 French lines, or 3.0 English inches, to prepare his great B. D. Catalogue of stars down to mag. 9.5, as estimated visually by him and his assistants; but a star to which he gave the mag. 9.5 has been found to have the mag. 10.6 on the Pogson scale. Evidently the eye cannot be trusted too far without checking the results experimentally. In 1876 E. C. Pickering, a physicist in the Massachusetts Institute of Technology, was appointed director of the Harvard College Observatory; and soon afterwards he devised a special photometer for the accurate determination of the magnitudes of all stars visible at Cambridge, not fainter than mag. 6. The observations for this programme were begun Oct. 28, 1879, and were completed Sept. 17, 1882. There are 4,260 stars in the catalogue published. Astronomers in Great Britain and on the continent undertook similar tasks with photometers of various types, and now the magnitudes of many thousands of stars have been determined with accuracy. Modern stellar photometers employ a photo-electric cell, which is very delicate and reliable.

Dr. Helen S. Hogg presented the ninth paper in the series on "Explorations in Clusters and Nebulae," dealing with the velocity-distance relationship. The first readable spectrum of an extragalactic nebula was obtained of M31 in Andromeda in 1899 and showed it to be a system of stars. Slipher in 1912 made the first velocity determination which showed that M31 had a velocity of approach of about 190 miles per second. First velocity determinations of the closer nebulae were all negative, showing they were apparently approaching; all the later determinations of other nebulae were positive, indicating recession. The tendency for velocities to increase with known distance led to formulation of the velocity-distance relationship. The increase is on the average about 100 miles per second for every million light-years of distance

of the nebula. The greatest velocity so far measured is about 26,000 mi./sec. for an object (Ursa Major No. 2) about 240,000,000 l.y. distant. This work on the velocity of very faint nebulae is one of the greatest observational triumphs of astronomy, 60 to 100 hours of exposure on eight to ten nights often being required. The most distant nebulae investigated are too faint (mag. 18) to be seen with the 100-inch telescope and the instrument must be set on the nebula by careful computation of its position with reference to a nearby star as measured on a photographic plate. The red shift (Doppler effect) observed in the distant nebulae indicates a very high velocity, almost one-sixth the speed of light, or else must be interpreted as representing some hitherto unrecognized principle in physics. The work on faint nebulae has been done with a special Rayton lens, with focal length about one-half the aperture and very high speed. Observations have been concentrated on the bright nebulae in clusters of nebulae, and spectra are now available for more than 300 nebulae with a dispersion of 1,000 Angstroms per millimetre at H. Some examples of velocity determinations are: Virgo clustr, 7,000,000 l.y., 1,400 mi./sec.; Ursa Major No. 1, 85,000,000 l.y., 9,400 mi./sec.; Gemini cluster, 135,000,000 l.y., 15,000 mi./sec.; Boötes cluster, 230,000,000 l.y., 24,500 mi./sec., and Ursa Major No. 2, 240, 000,000 l.y., 26,000 mi./sec. A long exposure spectrogram on a larger scale (500 A. per mm.) confirms the high velocity in the Boötes cluster and shows that the small-scale spectra can be interpreted reliably. Emission lines of mercury are found on all the long-exposure spectra made at Mount Wilson. These are due to the large number of lights in the valley near Los Angeles below. There are places in the sky where the camera reveals more extragalactic nebulae than stars in the area, Dr. Hogg added. "It is difficult to get a bird's-eye view of the universe as it is, because the farther out we go into space, the further back into time we of necessity have to go," she said in conclusion.

The Society instructed the Secretary to send a letter of sympathy to the mother of Lieutenant George Tidy of the Royal Navy who was reported missing in the recent action in which H.M.S. Exeter was lost in the Far East. Lieut. Tidy was a member of the Society and had been on the staff of the Dunlap Observatory before enlisting for special radio work.

FREDERIC L. TROYER, *Recorder.*

AT VANCOUVER

October 14, 1941.—The first meeting of the 1941-42 season, and the eighty-first since the founding of the Centre was held in the Science Building of the University of British Columbia. The President, Capt. C. A. MacDonald, introduced Mr. N. D. Blagdon Phillips who gave an address on "Sun-dials."

The speaker first described the parts of a sun-dial, then discussed the irregularities of time as recorded on a dial as compared to mean time as read from a clock, and explained the use of the equation of time. Slides of sun-dials of scientific and historic interest were shown. Some of these had adjusting mechanisms by which to correct for the equation of time, but Mr. Phillips

preferred a type using a point of light which could follow the equation of time rather than the ordinary straight line shadow of the gnomon.

This kind of dial needs no correction for the equation of time and has the added advantage of showing the date as well as the hour. If made with a white matt surface a very clear indication of the time is given, even with weak sunlight. A sun-dial of this type has a concave face and must be arranged to suit the latitude where it will be used. The principles involved in this latter kind of sun-dial were illustrated by a series of slides. An informal discussion followed the lecture.

November 18, 1941.—The meeting was held at the University of British Columbia, the President, Capt. C. A. McDonald in the chair. The speaker was Dr. J. A. Pearce, director of the Dominion Astrophysical Observatory, Victoria, who chose as his topic "Stellar Motions."

Dr. Pearce commenced with a brief historical review of the subject from the time of Bruno (1600) who first questioned the immobility of the stars, to Halley who showed that Sirius and other bright stars were not in the positions assigned to them on Ptolemy's map, and Herschel who showed that the sun was moving toward λ Herculis.

This "proper motion" was fairly easy to measure but the problem of radial velocity baffled astronomers for a longer period, especially since the key to the problem (i.e., the Doppler effect) was misinterpreted and thought to be the cause of the star's colour. Fizeau showed mathematically that this view was wrong and that the radial velocity is given by $v/c=\Delta\lambda/\lambda$. This formula was applied by Huggins, the first real astrophysicist, in 1860 to calculate the radial velocities of some stars. He also compared stellar and arc spectra, showed that nebulae were gaseous, and photographed stellar spectra in order to make more accurate measurements. However Vogel was the first astronomer to make precision measurements of the Doppler effect in the spectra of stars.

Dr. Pearce then detailed some of the difficulties which must be overcome for accurate work in this field. These include the necessity for thermal control of the spectrograph and corrections for the earth's motion about the sun. Slides of the early instruments were shown and then Dr. Pearce used illustrations from the work of himself and his associates at the Dominion Astrophysical Observatory.

Among other applications of spectroscopy to the motions of the heavenly bodies, the speaker discussed the rotations of the planets, the differential motion of Saturn's rings and the differential rotation of the surface of the sun with latitude. The Doppler effect provides also, a very powerful instrument for the investigation of double stars, their motions and perturbations.

Questions and discussion followed this extremely interesting and authoritative address, and following an expression of thanks to Dr. Pearce the meeting adjourned.

December 9, 1941.—Mr. Howard Edwards of the Meteorological Service was scheduled to speak on "Airline Weather Conditions over the Rockies," but blackout regulations resulted in cancellation of the meeting.

January 13, 1942.—The eighty-third meeting of the Centre was held in the usual place. The election of officers, postponed from the previous meeting, took place. Captain C. A. McDonald, the President, having rejoined the Navy, the vice-president, Mr. A. Outram, presided. Officers elected were as follows: *President*, Mr. A. Outram; *Vice-President*, Mr. N. D. B. Phillips; *Treasurer*, Mrs. Laura Anderson; *Corresponding Secretary*, Dr. H. D. Smith; *Recording Secretary*, Mr. R. E. G. Langton. The Council was changed by the addition of Mr. F. G. Berton. A motion that a letter of appreciation for his work with the Society be sent to Capt. McDonald was passed unanimously.

The speaker of the evening, Dr. H. V. Warren of the Department of Geology and Geography of the University of British Columbia, was then introduced by Mr. Outram. The topic chosen was "Minerals and Politics" and it was divided into two main sections, (1) Our own mineral problem, (2) Our mineral position relative to the war. Emphasizing the importance of mineral production, Dr. Warren stated that one-third of the weight and one-half of the freight revenue from Canadian railways comes from the mines, then passed on to reasons why the mining industry receives special consideration from government in respect to taxes.

Firstly, it is unpredictable, since new mineral discoveries or technical advances might at any time force a mine to close down because of a more economical production of ore in a different locality. Secondly, all mines are exhaustible and investments must be repaid during the mine's life. Thirdly, the opening of a new mine entails taking a chance with a considerable sum of money, both in the discovery and the development of the property. This necessary investment might come from the government, from companies or from individuals. Governmental control leaves loopholes for extravagance and other difficulties; small companies or individuals may be lucky or may not; but the large companies on the average will get enough back to make an adequate return on their investments. Dr. Warren deplored the lack of initiative in the present generation and stated the need for the pioneer type of individual who was not afraid of an intelligent gamble.

For the second section of his address Dr. Warren suggested that the audience ask questions. A large number of queries elicited much interesting information on the self-sufficiency, or lack of it, of Canada and others of the United Nations. The speaker held out no hope for the early collapse of the Axis due to mineral deficiency but suggested that in certain metals used in alloys they may ultimately be pinched. The meeting adjourned with a vote of thanks to Dr. Warren for a most timely and instructive address.

R. E. G. Langton, *Recording Secretary.*

The Royal Astronomical Society of Canada

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